MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2015/2016

EEE 3076 – POWER ELECTRONICS

(LE, EE, CE, NE)

16 OCTOBER 2015
3.00 PM – 5.00 PM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 10 pages including cover page with 4 Questions only.
2. Answer ALL questions. All questions carry equal marks and the distributions of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

a) Power electronic devices can be classified based on controllability. State the three classifications, describe briefly how the devices are controlled and give at least one example for each classification.

[9 marks]

b) A bipolar junction transistor (BJT) is used as a switch in a DC-DC converter connected to a load. The switching characteristic for the BJT is shown in Figure Q1. During OFF-state, V_{CE} = 100 V and I_C = 2.5 mA. During ON-state, V_{CE} = 2 V, I_C = 8 A, V_{BE} = 0.7 V and β = 100. Calculate the following:

(i) Static loss

[8 marks]

(ii) Dynamic loss

[6 marks]

(iii) Total loss

[2 marks]

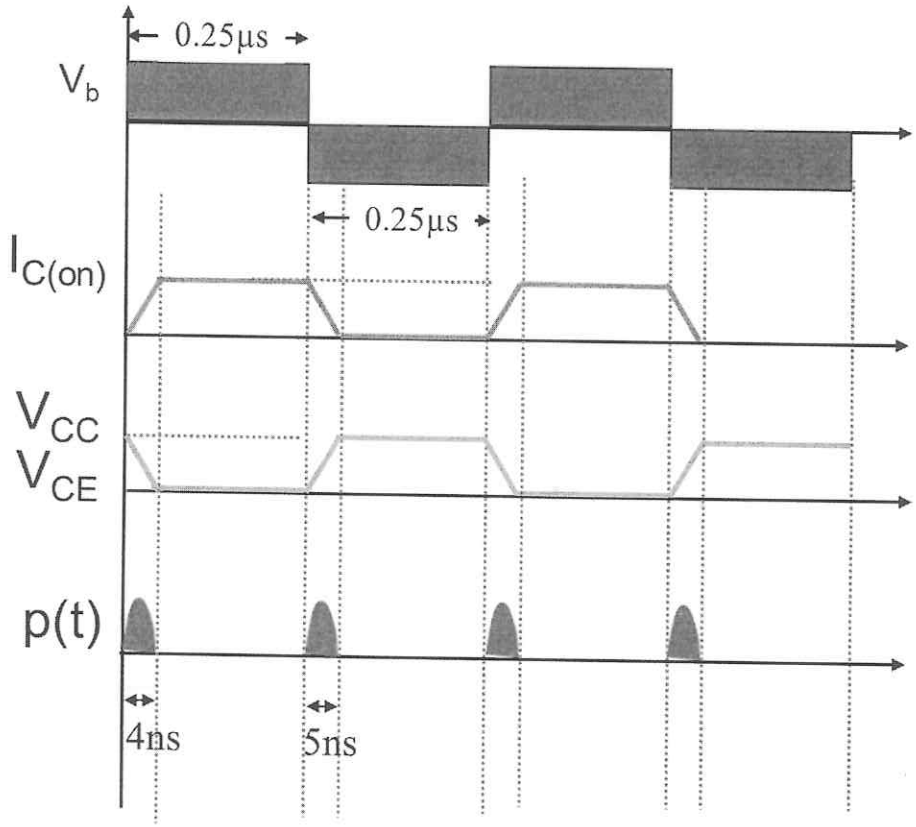

Figure Q1

Continued...

Question 2

A DC load with the following parameters is connected to an AC voltage source via a rectifier circuit. The block diagram is shown in Figure Q2.

DC load
Output Power = 6 kW, maximum allowable DC voltage = 300 V, R-L Load

Available AC sources
Single phase AC source, 230 V, 50 Hz.
Three phase AC source, 400 V, 50 Hz.

a) Sketch the circuit diagram of the rectifier.

[3 marks]

b) Sketch the waveforms of input voltage, output voltage, input current and output current. [Use the sheet in the appendix for sketching.]

[7 marks]

c) Calculate the average output voltage and current.

[4 marks]

d) Determine the minimum blocking voltage of the diode in the rectifier circuit.

[2 marks]

e) If four similar DC loads are to be connected in parallel at the output of rectifier,
   (i) Sketch the circuit of the new rectifier.

[5 marks]

   (ii) Calculate the average output voltage and current

[4 marks]

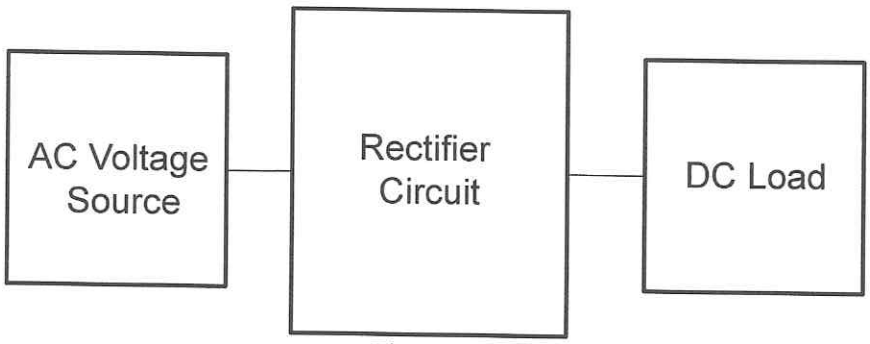

Figure Q2

Continued...

Question 3

(a) Figure Q3 (a) shows a buck converter circuit and its output voltage, V_o waveform. Design the parameters of the buck converter to power a load that consumes 15W. The duty cycle $D = 0.4$ and switching frequency $f_S = 20$ kHz. Assume that the buck converter will be operating in the continuous current mode and all the components are ideal.

[13 marks]

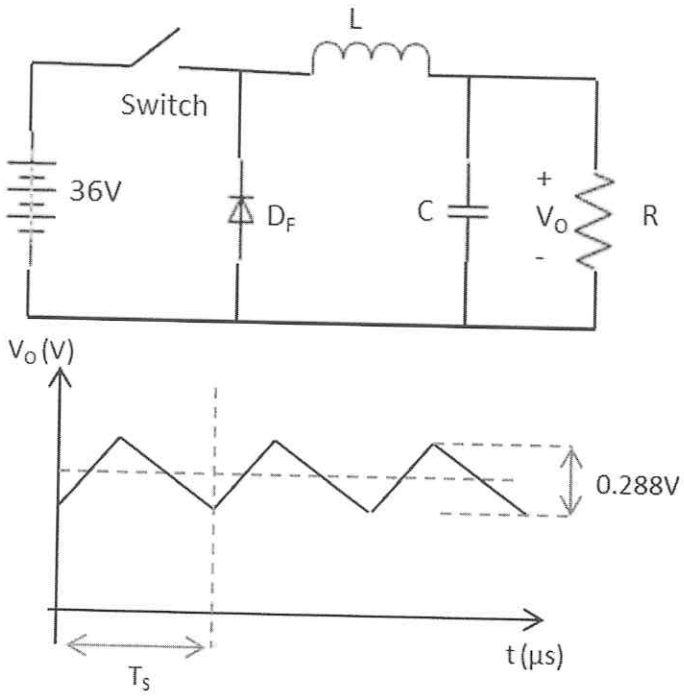

Figure Q3 (a)

(b) A flyback converter is shown in Figure Q3 (b). This converter can supply an output power of 120W at $V_o = 40$V from a 200 V input DC source. The switching period, T_s is 10 μs, the magnetizing inductor L_m is 600 μH and the transformer turns ratio, (N_1/N_2) is 2. Determine:

(i) The duty ratio, D.

[2 marks]

(ii) The maximum and minimum inductor currents (I_{Lmax} , I_{Lmin}).

[4 marks]

(iii) The average input current and average diode current.

[4 marks]

(iv) The value of the output capacitor so that the output ripple voltage is limited to 0.1% of the output voltage, V_o.

[2 marks]

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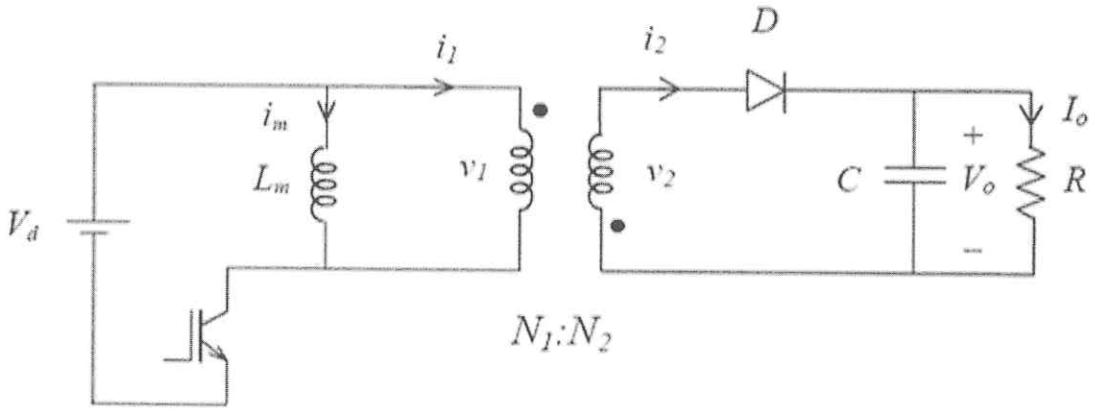

Figure Q3 (b)

Continued...

Question 4

a) A single phase inverter shown in Figure Q4(a) is used to supply an RL Load. Pulse Width Modulation (PWM) technique is used to control the switch.

(i) Calculate the r.m.s value of the fundamental output voltage and current if duty ratio is 0.5.

[3 marks]

(ii) Calculate the Total Harmonic Distortion of voltage (THD_V) considering the 3^{rd}, 5^{th} and 7^{th} harmonics.

[6 marks]

(iii) Calculate the Duty Ratio, D to eliminate 5^{th} harmonic. (Choose a suitable duty ratio larger than 0.5)

[4 marks]

(iv) Calculate the new THD_V considering 3^{rd} , 5^{th} and 7^{th} harmonics.

[5 marks]

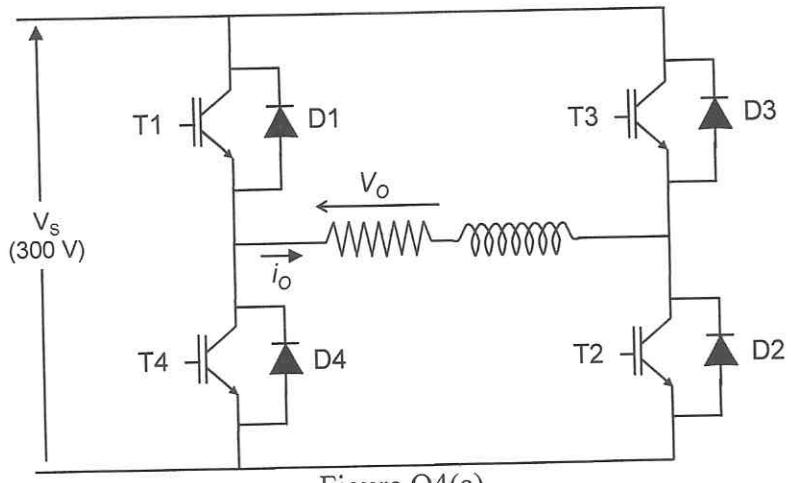

Figure Q4(a)

b) A series resonant inverter shown in Figure Q4(b) is used for an induction heater. Given the following circuit parameters

$R = 3\ \Omega$, $L = 40\mu H$, $C = 10\mu F$, Output frequency = 5 kHz,

(i) Determine the operation mode (overlapping or non-overlapping) of the inverter.

[5 marks]

(ii) Calculate the maximum permissible output frequency if IGBT off time is 50 ns.

[2 marks]

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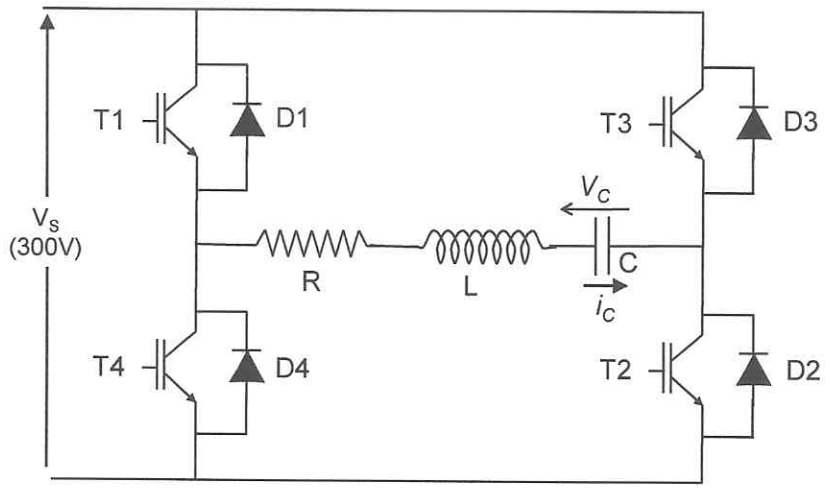

Figure Q4(b)

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Appendix (For Question 2(b))

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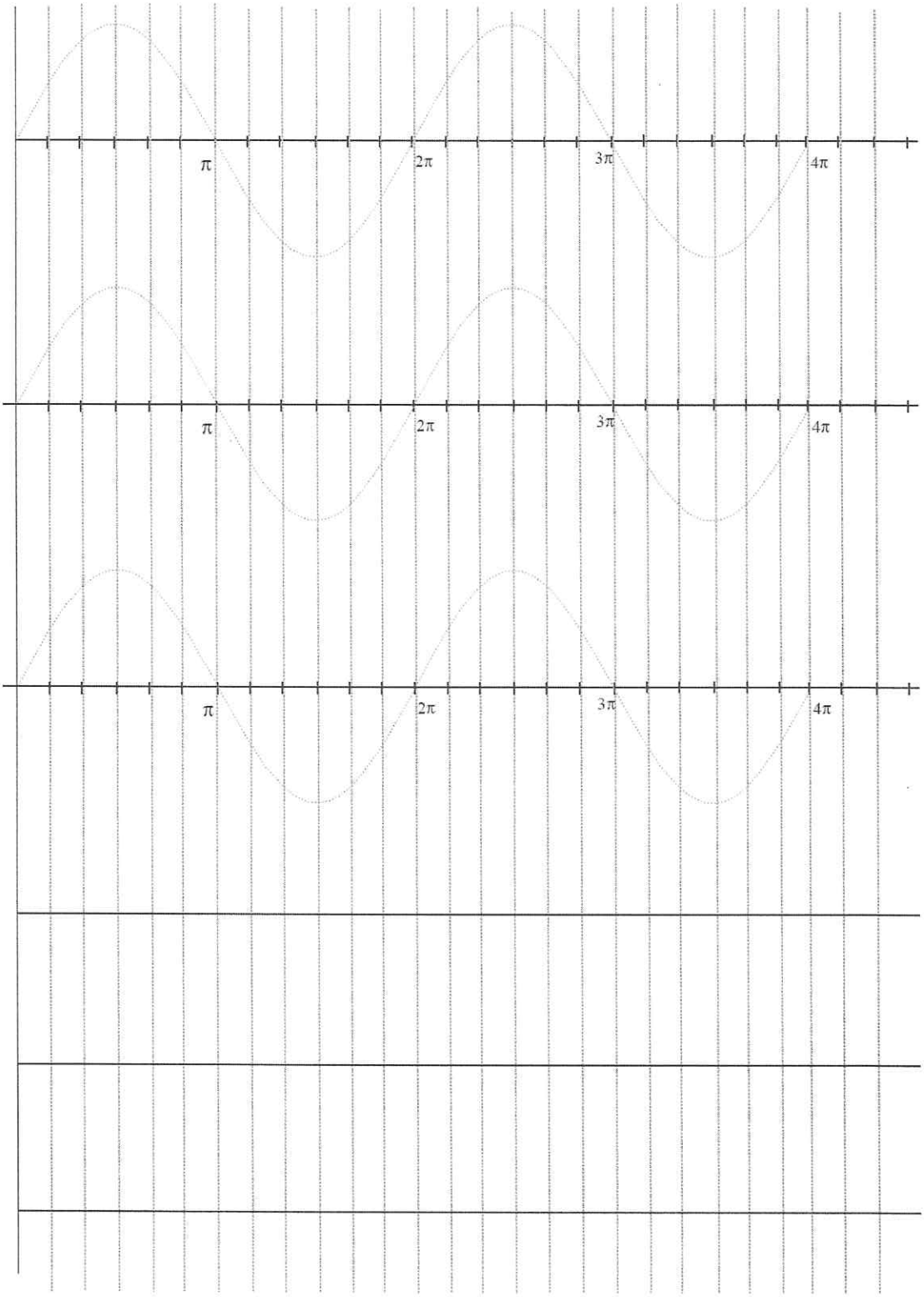

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Examination Formula Sheet (Rev 2.0)

AC-DC Converters

Single Phase Uncontrolled Rectifiers (Half wave) , R load	Single Phase Uncontrolled Rectifiers (Half wave), RL Load
$V_{o,avg} = \frac{\sqrt{2}V_{S,rms}}{\pi}$, $V_{o,rms} == \frac{V_{S,rms}}{\sqrt{2}}$	$V_{o,avg} = \frac{\sqrt{2}V_{s,rms}}{2\pi}[1-\cos(\beta)]$ $V_{o,rms} = \frac{V_{s,rms}}{\sqrt{2\pi}}\sqrt{\beta - \frac{\sin 2\beta}{2}}$ $\beta \approx \pi + \theta$, $\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$
Single Phase Uncontrolled Rectifiers (Bridge Full wave)	Three Phase Uncontrolled Rectifiers (Half wave)
$V_{o,avg} = \frac{2\sqrt{2}V_{s,rms}}{\pi}$, $V_{o,rms} = V_{s,rms}$	$V_{o_avg} = \frac{3\sqrt{3}V_{l-n}}{\sqrt{2}\pi}$, $V_{0_rms} = 1.19V_{l-n}$
Three Phase Uncontrolled Rectifiers (Full wave)	Single Phase controlled Rectifiers (Half wave)
$V_{0_avg} = \frac{3\sqrt{2}V_{l-l}}{\pi}$, $V_{0_rms} = 0.963\ V_{l-l}$	$V_{0_avg} = \frac{V_{S,rms}}{\sqrt{2}\pi}(1+\cos\alpha)$ R Load $V_{0_avg} = \frac{V_{S,rms}}{\sqrt{2}\pi}(\cos\alpha + \cos\beta)$ RL Load
Single Phase controlled Rectifiers (Bridge Full wave)	Three Phase controlled Rectifiers (Half wave)
$V_{0_avg} = \frac{\sqrt{2}V_{S,rms}}{\pi}(1+\cos\alpha)$ R Load $V_{0_avg} = \frac{2\sqrt{2}V}{\pi}\cos\alpha$ RL Load	$V_{0_avg} = \frac{3\sqrt{2}}{2\pi}V_{AN}\left(1+\cos\left(\pi/6+\alpha\right)\right)$
Three Phase controlled Rectifiers (Full wave)	
$V_{0_avg} = \frac{3\sqrt{6}}{\pi}V_{AN}\left(\sin\left(\pi/6+\alpha\right)\right)$	

DC-DC Converters

Buck Converter (CCM)	Buck Converter (DCM)
$V_o = DV_d$ $I_{L\max} = V_o\left[\frac{1}{R} + \frac{(1-D)}{2Lf_s}\right]$ $I_{L\min} = V_o\left[\frac{1}{R} - \frac{(1-D)}{2Lf_s}\right]$	$\frac{V_o}{V_d} = \frac{D}{D+\Delta_1}$ $I_o = \frac{V_d T_s}{2L}D\Delta_1$

Continued…

DC-DC Converters (cont.)

Boost Converter (CCM)	Boost Converter (DCM)
$V_o = \frac{V_d}{1-D}$ $I_{L\max} = \frac{V_d}{(1-D)^2 R} + \frac{V_d D T_s}{2L}$ $I_{L\min} = \frac{V_d}{(1-D)^2 R} - \frac{V_d D T_s}{2L}$	$\frac{V_o}{V_d} = \frac{\Delta_1 + D}{\Delta_1}$ $I_o = \frac{V_d T_s}{2L} D\Delta_1$
Buck-Boost Converter (CCM)	**Buck-Boost Converter (DCM)**
$V_o = \frac{V_d D}{1-D}$ $I_{L\max} = \frac{V_d D}{R(1-D)^2} + \frac{V_d D T_s}{2L}$ $I_{L\min} = \frac{V_d D}{R(1-D)^2} - \frac{V_d D T_s}{2L}$	$\frac{V_o}{V_d} = \frac{D}{\Delta_1}$ $I_o = \frac{V_d D}{2 f_s L}(D + \Delta_1) - \frac{D I_o}{\Delta_1}$
Flyback Converter (CCM)	**Flyback Converter (DCM)**
$\frac{V_o}{V_d} = \frac{N_2}{N_1}\frac{D}{1-D}$ $I_{L\max} = \frac{V_d D}{R(1-D)^2}\left[\frac{N_2}{N_1}\right]^2 + \frac{V_d D T_s}{2L_m}$ $I_{L\min} = \frac{V_d D}{R(1-D)^2}\left[\frac{N_2}{N_1}\right]^2 - \frac{V_d D T_s}{2L_m}$	$\frac{V_o}{V_d} = D\sqrt{\frac{R}{2 f_s L_m}}$ $I_o = \frac{V_o}{R}$

DC- AC Converters

Single-Phase Half-bridge Inverter with RL load

$$v_o(\omega t) = \sum_{n=1,3,5,\ldots}^{\infty} \frac{2V_s}{n\pi}\sin(n\omega t)$$

Single-phase full-bridge PWM inverter (Square Wave)

$$v_o(\omega t) = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4V_s}{n\pi}\sin(n\omega t)$$

Single-phase full-bridge PWM inverter (Quasi Square Wave)

$$v(\omega t) = \sum_{n=1,3,5\ldots}^{\infty} \frac{4V_s}{n\pi}\sin\frac{nD\pi}{2}\cos n(\omega t - \frac{D\pi}{2})$$

Resonant Converters

$$\omega_r = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

End of Paper